APPENDIX E

THE DEVELOPMENT AND COMPARISON OF CONDITION RATINGS

1. INTRODUCTION

From the late 1960s to 1992, the overall measure of pavement condition as used by WSDOT was the Pavement Condition Rating (PCR) scheme. During 1992, WSDOT began the process of changing to a new overall distress measure: Pavement Structural Condition (PSC).

Each of these rating schemes (old and new) will be described, then compared.

2. PAVEMENT CONDITION RATING (PCR)

The PCR was used by WSDOT to provide an overall measure of pavement condition for both flexible and rigid pavements up to 1992. Essentially, it was a function of four distress types for flexible pavements and three for rigid pavements. The weighting values for flexible pavements are shown in Table E-1 and are applied to the following distress types:

(a) fatigue (alligator) cracking,
(b) longitudinal cracking,
(c) transverse cracking, and
(d) patching.

The weighting values for rigid pavements are shown in Table E-2 and are applied to the following distress types:

(a) slab cracking,
(b) spalling at joints and cracks, and
(c) faulting, settlement.

WSDOT currently surveys additional types of distress, as illustrated in Figure E-1, but used only those listed in Tables E-1 and E-2 for PMS purposes. The final Pavement Condition Rating (PCR) was a combination of the visual rating and ride rating:

Table E-1. Flexible Pavement Defect Deductions for PMS

				Percent of Wheel Track Length			
				1-24	25-49	50-74	75+
Alligator Cracking		(1)	Hairline	20	25	30	35
		(2)	Spalling	35	40	45	50
		(3)	Spalling & Pumping	50	55	60	65
				Average Width in Inches			
				1/8-1/4	1/4+	Spalled	
Longitudinal Cracking	Lineal Feet per 100 feet	(1)	1-99	5	15	30	
		(2)	100-199	15	30	45	
		(3)	200+	30	45	60	
				Average Width in Inches			
				1/8-1/4	1/4+	Spalled	
Transverse Cracking	Number per 100 feet	(1)	1-4	5	10	15	
		(2)	5-9	10	15	20	
		(3)	10+	15	20	25	
				Type of Patch			
				BST	Blade	AC	
Patching	Percent Area per 100 feet	(1)	1-5	20	25	30	
		(2)	6-25	25	30	35	
		(3)	25+	30	40	50	

Table E-2. Portland Cement Concrete Defect Deductions for PMS

				Percent of Panels		
				1-25	26-50	51+
Cracking Averaging 1/8+	Units per Panel Length	(1)	1-2	5	10	20
		(2)	3-4	10	20	35
		(3)	4+	15	30	50
				Percent of Joints		
				1-15	16-50	51+
Spalling at Joints and Cracks	Average Width in Inches	(1)	1/4-1	5	10	15
		(2)	1-3	10	20	30
		(3)	3+	15	30	50
				Percent of Panels		
				1-15	16-35	36+
Faulting, Settlement	Average Displacement in Inches	(1)	1/8-1/4	5	10	20
		(2)	1/4-1/2	10	20	30
		(3)	1/2+	15	30	40

$$PCR = [100-\Sigma D]\left[1.0 - .3\left(\frac{CPM}{5000}\right)^2\right]$$

where ΣD = sum of the defect values (Tables E-1 and E-2) and
CPM = counts per mile from a Cox Road Rater.

The ride input in the equation had little effect except for the worst conditions. As can be seen by the relative defect values, the PCR was largely a measure of fatigue cracking for flexible pavements and cracking for PCC slabs. The first stages of fatigue cracking for flexible pavements was evident at a PCR of about 40 (this assumes other distress will generally be present). Service lives were generally estimated at a PCR of 40 which is close to a Pavement Serviceability Index (PSI) of 3.0. Normally, there was (or is) no significant roughness from distressed pavement at this stage.

Though the PCR scheme worked well, it had deficiencies that were largely corrected by PSC.

3. PAVEMENT STRUCTURAL CONDITION (PSC) — FLEXIBLE

3.1 Introduction

The PSC replaces the PCR previously described. Some of the reasons for changing the flexible pavement condition rating scheme include:

(a) Improve the assessment of the structural value of the surfacing material (either asphalt concrete (AC) or bituminous surface treatment (BST)) for the rehabilitation scoping process (refer to Appendix A). More specifically, it is an attempt to estimate, in an analogous sense, the "conversion factor" as illustrated in various overlay design methods.

(b) Improve the manner in which various pavement distress types are combined to represent a specific pavement segment.

(c) Use essentially the same WSDOT distress survey results. The specific distress types and associated extents and severities are described in Reference E-1.

(d) The PSC ranges from 100 (best) to 0 (worst). The prior PCR scale had an open-ended lower scale (potentially a negative PCR of -100 was possible for flexible pavements and -40 for rigid pavements).

(e) The PSC produces an improved performance curve (PSC vs. Age). Specifically, the influence of longitudinal and transverse cracking is better incorporated into the PSC.

(f) Alligator cracking, as incorporated into the PSC score, can more easily "force" a pavement segment into the rehabilitation mode. The logic for this is straightforward in that rehabilitation is least expensive if the project is programmed early in the fatigue cracking cycle.

(g) The PSC scheme will better accommodate automated distress survey techniques which will likely provide "continuous" measures of pavement distress.

3.2 Calculation of PSC — Flexible

3.2.1 Overall Rating

The PSC is calculated as follows:

$$PSC = 100 - \text{deduct points} \qquad \text{(Eq. 1)}$$

$$= 100 - 15.8\,(EC)^{0.5}$$

where PSC = Pavement Structural Condition Flexible

EC = equivalent cracking, which is a composite of alligator, longitudinal, transverse cracking, and patching.

The EC is an additive function as follows:

$$EC = ACEC + LCEC + TCEC + PTEC \qquad \text{(Eq. 2)}$$

where EC = total equivalent cracking,

ACEC = alligator cracking component of equivalent cracking,

LCEC = longitudinal cracking component of equivalent cracking,

TCEC = transverse cracking component of equivalent cracking, and

PTEC = patching cracking component of equivalent cracking.

Equation 1 was obtained from the following data:

PSC	Percent Alligator Cracking (Spalling and Pumping, AC3)
100	0
50	10
0	40

The equation was obtained by "selecting" various "powers" and obtaining the b_1 intercept by regression. The power and b_1 which produced the least error were selected. The resulting equation was

$$PSC = 100.0 - 15.8114\ (AC3)^{0.5}$$

or

$$PSC = 100.0 - 15.8\ (AC3)^{0.5}$$

$R^2 \simeq 100.0\%$
SEE $\simeq 0.0$
$n = 3$

All other forms of cracking are in terms of AC3, thus the term EC is substituted for AC3.

3.2.2 Alligator Cracking Component

The alligator (or fatigue) cracking component of equivalent cracking is estimated as follows:

$$ACEC = AC3 + 0.445\ (AC2)^{1.15} + 0.13\ (AC1)^{1.35} \qquad \text{(Eq. 3)}$$

where ACEC = alligator cracking component of equivalent cracking,

AC1 = percent of wheelpath length with hairline alligator cracking,

AC2 = percent of wheelpath length with spalled alligator cracking, and

AC3 = percent of wheelpath length with spalled and pumping alligator cracking.

The percentages of alligator cracking are obtained directly from the WSDOT visual distress survey.

The basis for Equation 3 follows:

	Percent Alligator Cracking		
Deduct Points	Hairline (AC1)	Spalling (AC2)	Spalling + Pumping (AC3)
0	0	0	0
50	25	15	10
100	70	50	40

Essentially, the AC or BST surfacing is assumed to have no structural value (other than a crushed stone base) at alligator cracking levels of 70 percent of the wheel tracks for the hairline level of severity, 50 percent at the spalling level of severity and 40 percent at the spalling and pumping level of severity. Further, about 10 percent of spalling and pumping alligator cracking is a point where a pavement segment should be programmed for some type of rehabilitation treatment. This is approximately equivalent to a PSI of 3.0 (AASHTO definition).

The terms shown in Equation 3 are all based on the spalling and pumping severity level (i.e., AC3). This was achieved by regressing AC1 against AC3 and AC2 against AC3. The regression was performed by trying various exponents ("powers") for AC1 and AC2. The "best" combination of exponent and intercept (b_1) was selected. The following model was used:

$$AC3 = b_0 + b_1 (AC1 \text{ or } AC2)^{power}$$

(a) $AC3 = f(AC1)$

Using the AC3 severity level as a common basis for alligator cracking, equate AC1 in terms of AC3.

Percent AC1		Percent AC3
0	=	0
25	=	10
70	=	40

The resulting regression equation is:

$$AC3 = 0.017 + 0.129 (AC1)^{1.35}$$

$$AC3 \cong 0.13 (AC1)^{1.35}$$

$R^2 \cong 100.0\%$
$SEE \cong 0.029$
$n = 3$

(b) $AC3 = f(AC2)$

Again, using the AC3 severity level as the common basis for alligator cracking, equate AC2 in terms of AC3.

Percent AC2		Percent AC3
0	=	0
15	=	10
50	=	40

The resulting regression equation is

$$AC3 = -0.008 + 0.4449\,(AC2)^{1.15}$$

$$AC3 \cong 0.445\,(AC2)^{1.15}$$

$$R^2 \cong 100.0\%$$
$$SEE \cong 0.014$$
$$n = 3$$

3.2.3 Longitudinal and Transverse Cracking Components

3.2.3.1 Introduction

To convert a measure of longitudinal cracking to equivalent alligator cracking, assume that the pavement lane wheel path is divided into 1 ft wide by 1.5 ft long blocks. If each wheel path is 3 ft wide (total of 6 ft) then there are 6 blocks in width and 67 blocks in a 100-ft section length. Refer to Figure E-2 for an illustration of this. The question becomes what amount of longitudinal and transverse cracking is equivalent to alligator cracking? Again, the basis for this estimate will be in terms of AC3.

The basic assumption is that if each 1.5-ft x 1.5-ft block contained a fully developed longitudinal and transverse crack, then this approximates an equivalent amount of alligator cracking of corresponding severity.

3.2.3.2 Alligator Cracking as a Function of Longitudinal Cracking

A fully cracked block (1.5- x 1.5-ft block with a full transverse crack and a full longitudinal crack) is assumed to be equivalent to the same area of alligator cracking; thus,

100 % of wheel track is alligator cracking

= 6 longitudinal cracks + 66.7 transverse cracks
= $6(100) + 66.7(6) \cong 1{,}000$ ft of cracking
≅ 10 longitudinal cracks (full 100 ft section length)

Thus, equivalent longitudinal cracking (LC) is approximately equal to 0.1 equivalent AC,

or 10 longitudinal cracks = 100 percent of both wheeltracks with alligator cracking

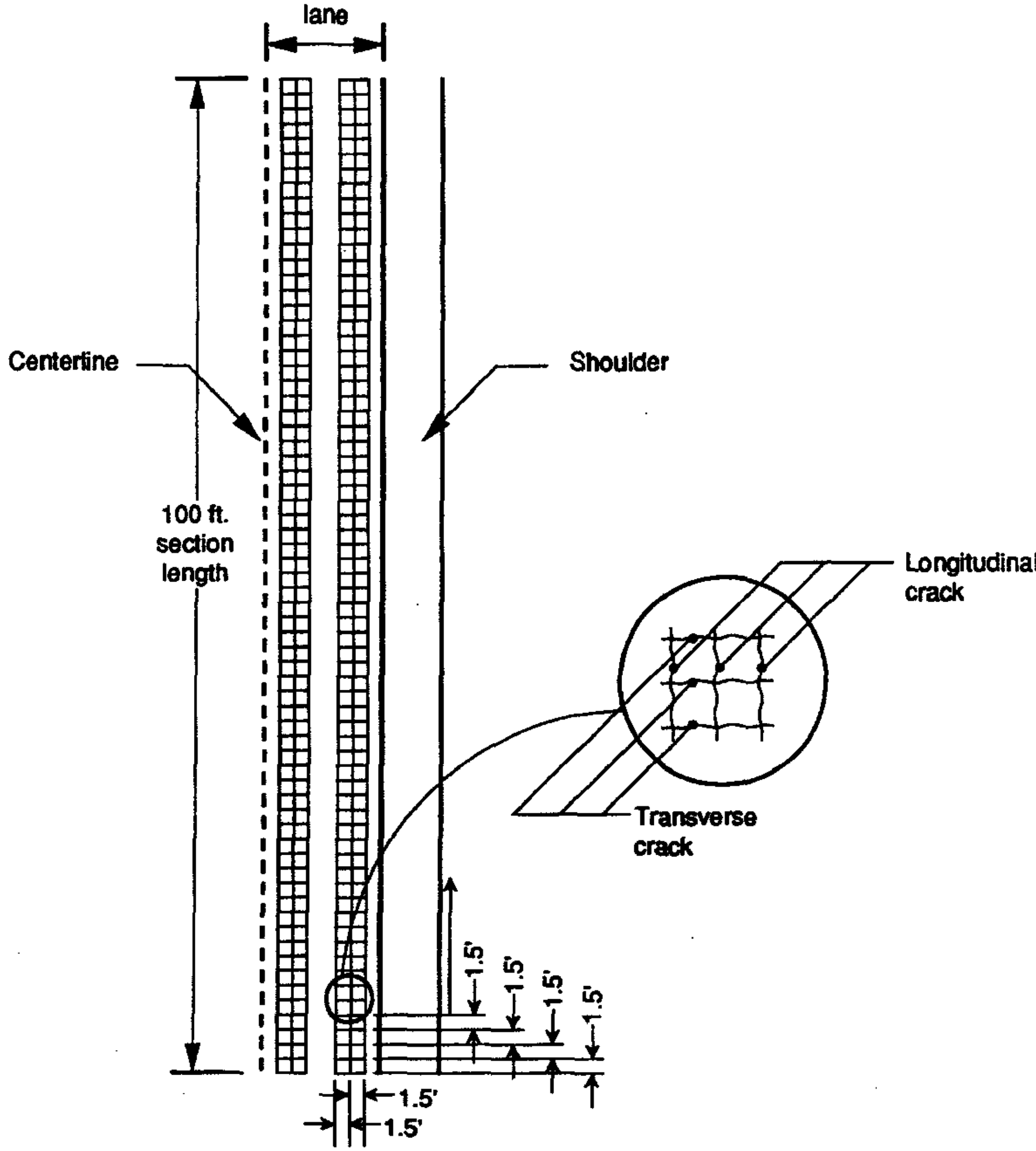

Figure E-2. Illustration of Wheel Path Blocks or as a ratio

$$\frac{10\ LC}{100\%\ AC} = \frac{1\ LC}{10AC}$$

or $0.1\ LC = 1.0\ AC$

The resulting LCEC equation is (substituting <u>0.1 LC</u> for <u>1.0 AC</u> at all severity levels into Equation 3):

$$LCEC = (0.1\ LC3) + 0.445\ (0.1LC2)^{1.15} + 0.13\ (0.1LC1)^{1.35} \quad \text{(Eq. 4)}$$

where LCEC = longitudinal cracking component of equivalent cracking,

LC1 = percent of section length with a less than 1/4 in. width severity level,

LC2 = percent of section length with a greater than 1/4 in. severity level, and

LC3 = percent of section length with a spalling severity level.

3.2.3.3 Alligator Cracking as a Function of Transverse Cracking

Using the same scheme as described in paragraph 3.2.3.2 for longitudinal cracking, the equivalent alligator cracking as a function of transverse cracking is:

100% of wheel track is alligator cracking

= 67 transverse cracks (6 ft)
+ 6 longitudinal cracks) (100 ft)
≃ 1,000 ft

Number of <u>full</u> transverse cracks (as surveyed 12 ft long transverse cracks) ≃ 1,000 ft/12 ft ≃ 83 cracks

Thus, 83 "full" transverse cracks = 100 percent of both wheeltracks with alligator cracking

or as a ratio

$$\frac{83\ LC}{100\ AC} = = 0.83 \simeq 0.8$$

or $0.8\ TC = 1.0\ AC$

The resulting LCEC equation is (substituting <u>0.8 TC</u> for <u>1.0 AC</u> at all severity levels into Equation 3):

$$TCEC = (0.8\ TC3) + 0.445\ (0.8TC2)^{1.15} + 0.13\ (0.8TC1)^{1.35}$$

where TCEC = transverse cracking component of equivalent cracking,

TC1 = number of transverse cracks per 100 ft of section length with a less than 1/4-in. width severity level,

TC2 = number of transverse cracks per 100 ft of section length with a greater than 1/4-in. width severity level, and

TC3 = number of transverse cracks per 100 ft of section length with a spalling severity level.

3.2.4 Patching Component

The following assumptions are used in order to equate patching to alligator cracking:

(a) A full depth AC digout is equivalent to pumping severity level for alligator cracking.

(b) A blade (or cold mix) patch is equivalent to 75 percent spalled alligator cracking.

(c) A BST (or chip seal) patch is equivalent to 75 percent hairline alligator cracking.

Thus the resulting PTEC equation is:

$$PTEC = PT3 + 0.445\ [0.75(PT2)]^{1.15} + 0.13\ [0.75(PT1)]^{1.35}$$

where PTEC = patching component of equivalent cracking,

PT1 = percent of wheel track length with BST patching,

PT2 = percent of wheel track length with blade patching, and

PT3 = percent of wheel track length with full depth patching.

3.3 Illustration of PSC — Flexible Calculations

Now that the basic derivation of the PSC has been covered, a few illustrative calculations follow. These will be based on "typically" observed distress types and quantities.

3.3.1 Low to Moderate Amount of Alligator and Longitudinal Cracking

Calculate PSC for the following conditions:

(a) Alligator cracking: 5 percent of wheel track (hairline severity)

(b) Longitudinal cracking: 150 ft. per station with an average crack width of less than 1/4 in.

(c) PSC = $100 - 15.8\ (EC)^{0.5}$, and

$$EC = 0.13\ (5)^{1.35} + 0.13\ ((0.1)(150))^{1.35}$$

$$= 1.142 + 5.031 = 6.173$$

Thus, PSC = $100 - 15.8\ (6.173)^{0.5} \cong 61$. The prior corresponding value for PCR = $100 - (20 + 15) = 65$

3.3.2 Low to Moderate Amount of Longitudinal Cracking and Patching

Calculate PSC for the following conditions:

(a) Longitudinal cracking: 50 ft. per station with an average crack width greater than 1/4 in.

(b) Patching: approximately 5 percent of the lane has received a BST patch.

(c) PSC = $100 - 15.8\ (EC)^{0.5}$, and

$$EC = 0.445\ ((0.1)(50))^{1.15} + 0.13\ (0.75\ (5))^{1.35}$$

$$= 2.833 + 0.774 = 3.607$$

Thus, PSC = $100 - 15.8\ (3.607)^{0.5} \cong 70$. The corresponding value for PCR = $100 - (15 + 20) = 65$.

3.3.3 Moderate Amount of Alligator Cracking and Patching

Calculate PSC for the following conditions:

(a) Alligator cracking: 25 percent of wheel track (hairline severity)

(b) Patching: 10 percent of the lane has received an AC patch

(c) $\quad PSC = 100 - 15.8\,(EC)^{0.5}$, and

$$EC = 0.13\,(25)^{1.35} + (10)$$

$$= 10.027 + 10.0 = 20.027$$

Thus, $PSC = 100 - 15.8\,(20.027)^{0.5} \cong 29$. The corresponding value for PCR = 100 - (25 + 35) = 40.

3.3.4 High Amount of Alligator Cracking and Patching

Calculate PSC for the conditions in the previous paragraph, except change the alligator cracking from hairline to spalling severity.

$$PSC = 100 - 15.8\,(EC)^{0.5}$$

$$EC = 0.445\,(25)^{1.15} + (10)$$

$$= 18.030 + 10.0 = 28.030$$

Thus, $PSC = 100 - 15.8\,(28.030)^{0.5} \cong 16$. The corresponding value for PCR = 100 - (40+35) = 25.

4. PAVEMENT STRUCTURAL CONDITION (PSC) — RIGID

4.1 Introduction

To be consistent in rating scheme terminology, the PSC — rigid will be used as the overall measure of rigid pavement condition. As of June 1993, the PSC will be calculated by use of the Washington State Distress Rating Manual [E-1] and distress deducts in terms of equivalent cracking. Four of the six distress types used for WSDOT rigid pavements are, in part, based on the original Pavement Condition Index (PCI) scheme, as will be subsequently described.

4.2 Original PCI Scheme

The rigid pavement PCI as described by Shahin and Kohn [E-2] is calculated from up to 19 different surface distress types as follows:

(a) Blow-up/buckling/shattering
(b) Corner break
(c) Divided slab
(d) Durability ("D") cracking
(e) Faulting
(f) Joint seal damage
(g) Lane/shoulder drop off
(h) Linear cracking